

## THE CERES S'COOL PROJECT: OPERATIONAL BUT NOT ROUTINE

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### 1. INTRODUCTION

The first Clouds and the Earth's Radiant Energy System (CERES) instrument has been returning useful data on Earth's radiation budget from the Tropical Rainfall Measuring Mission (TRMM) spacecraft since late 1997. Validation of the initial data is now intensively underway. As one component of this validation, the CERES Students' Cloud Observations On-Line (S'COOL) project has been operational since April 1998 - the 2nd CERES validation month. S'COOL involves school children in over 140 schools in 15 countries on 5 continents in making and reporting observations and measurements which they and CERES scientists can then compare to the satellite retrievals. The project is planned to continue through the life of the CERES Project (nominally 15 years), and new participants are invited to join on a continuous basis.

This paper will report on the first year of the operational phase of the project, during which a number of exciting events occurred (a demonstration of the project to First Lady Hillary Rodham Clinton, and visits by CERES personnel to participating schools, among others). It will further report on some of the noteworthy observations and comparisons which have been made possible by this project. We have found that schools are often located in interesting places, in terms of the clouds found there and the satellite's ability to observe these clouds. The paper will also report on the learning opportunities delivered by this project, and on new questions about the planet and its climate which arise in the students' minds as a result of their active participation.

### 2. PROJECT DEVELOPMENT

The S'COOL Project was developed in a phased approach over the course of a calendar year. Reports

on the early phases are given in Reference 1. Each phase encompassed an increasing number of participants and a wider geographic area. Phases 4 and 5 were held in October 1997 and February 1998, respectively, and followed local and national test phases.

During the development phases, various existing satellites were used as a stand-in for the yet-unlaunched CERES instrument. This allowed teachers and students to practice making observations at specific overpass times. These satellites (NOAA and GOES weather satellites, as well as Meteosat) allow us to retrieve information on cloud properties similar to that provided by CERES and its companion imager instruments.

The TRMM satellite carrying the first CERES instrument into orbit was finally launched on Thanksgiving Day, 1997, from the Tanegashima space center in Japan. The instrument covers were opened a month later after spacecraft outgassing was mostly complete, and the instrument began returning data. At a 35 degree inclination, the TRMM satellite has a ground track that drifts around the globe over a 46 day period. This means that at times it sees a given area only at night; and also that it can't see beyond about 40 degrees north or south latitude. For these reasons, participants are given a choice of observing at the overpass times of either the TRMM or the NOAA-12 or -14 spacecraft. Upon launch of the EOS-AM spacecraft into a polar orbit in mid-1999, that spacecraft will replace the NOAA options.

### 3 PROJECT OPERATION

The operational phase of the S'COOL project began officially in April 1998 and will continue for a number of years. The anticipated duration of the CERES experiment is 15 years. Teachers can participate at a time and for a duration which best fits their particular curriculum and the level and interest of their students. The S'COOL project will continue to be dynamic, with periodic additions of information to the website and continuing development of other materials. Teacher workshops and other activities are now being piloted locally.

There are six main elements of the Operational

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Configuration of the CERES S'COOL Project, described below.

### 3.1 Registration

Interested teachers can register to participate via e-mail, mail, fax, or telephone (contact information below). We request the teacher and school name, school address, grade level, postal and e-mail (if available) address, whether or not Internet access is available, and the location (city, state and country, as well as latitude and longitude, if known). We also like to know how a teacher heard about the project, to help us track the flow of information about it. Upon registration teachers are given a login ID and sent a set of materials. There is no participation fee.

### 3.2. Overpass Determination

When ready to start observing, the teacher or a student will access the S'COOL website and fill in a form with start and stop dates, along with their latitude and longitude and the offset from GMT to local time. Information to help them determine these values is available on the website. Overpass times for their location will be returned. Those without Internet access can request overpass times via E-mail, mail, fax or phone. From the list, which will typically include several choices each day, a teacher can select an overpass that best fits the class schedule.

### 3.3 Observe and Record Cloud and Surface Properties

Both the S'COOL poster and the website offer a concise explanation and description of the things the students need to observe and record, as well as instructions and tips for doing so. All observations can be made with materials on-hand in the classroom, though a set of weather instruments is useful.

### 3.4 Transmit Results to NASA

The results can be reported to NASA via the Internet form, e-mail (a template should be used to facilitate automatic processing), mail or fax. They will then be placed in a database which is accessible via the Internet.

### 3.5 Compare to Satellite Observations

Once CERES is providing cloud data on a routine basis, results matching participating S'COOL locations will be collected, averaged, and placed in an Internet database. AVHRR and GOES data from the development phase are currently available. The satellite and surface databases can be queried over the Internet via a single interface. Entries matching in latitude/longitude and/or a time interval can be retrieved, as can searches on a few other items. The results are displayed on a

web page, and can be downloaded in a spreadsheet format for further examination by the students. For those who don't have Internet access, results can also be obtained by written request. It is hoped that creative students will learn many interesting things from these comparisons, and that they may even bring new knowledge and ideas to the CERES scientists. Validation of a global dataset is limited by the data and the people available to study it. The S'COOL project has the potential to be an important contributor to both.

The S'COOL data are also available to the CERES Science Team and the atmospheric science research community as a whole. At a minimum, scientists may find the clear sky observations from S'COOL very valuable in their validation efforts. Other uses of the data, such as estimating cloud base, are also possible.

#### 3.5.1 Examples

In preparing for school visits (see Section 4.2), a few of the S'COOL observations have been scrutinized. Even this small sample has produced some very interesting comparisons:

- **Clear-Sky:** a number of school visits have occurred on perfectly clear days. While at first glance this may seem disappointing to the students, it allows us to make a very important point: determination of totally clear sky is trivial from the ground; but not so from space. A report from the students of completely clear sky is invaluable for CERES validation efforts.

- **Clouds over snow:** a number of participating schools in the Alps and the Jura mountains have illuminated this problem. Since snow can be both as cold and as bright as clouds, Fig. 1, it can cause problems in the cloud retrieval algorithms.

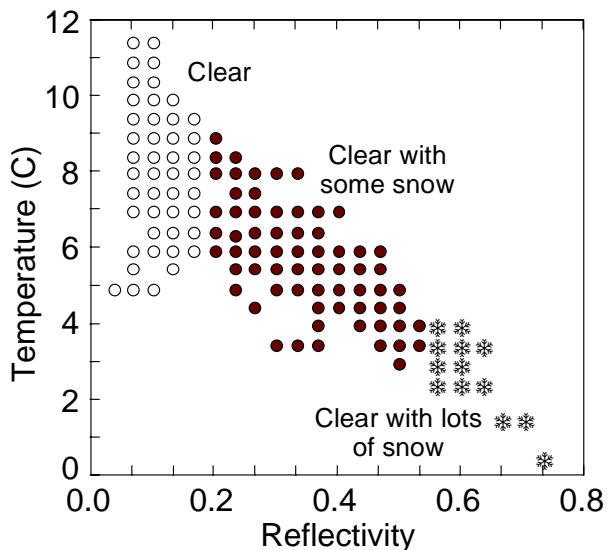


Figure 1. Temperature vs. Reflectivity for a scene of clear sky over snow. Normally all points in the bottom right - cold and bright - would be interpreted as cloud

- **Sub-pixel Clouds:** a participating location in Bunnell, FL has provided some examples of this problem. It is quite typical in this area to see the development through the day of cumulus clouds. These start very small and grow through the afternoon, often turning into thunderstorms. Early in their life cycle, these clouds are smaller than the imager pixel size (a few km) and very hard to detect from space - but not from the ground.

- **Multi-layer clouds:** these have occurred at a number of locations. In such situations the ground and satellite observations may differ; but both can be correct. This results from the fact that cloud layers cannot be detected through an opaque lower or higher layer. Detection of multi-layer cloud systems is stretching the state-of-the-art for satellite instruments. Ground observations of the lower layers can be very helpful in validating our progress in this area.

### 3.5.2 Statistics

An objective comparison of the satellite and ground-based data now in the S'COOL database was carried out by the second author. Matches were available only for a small subset of the database due to a number of factors: arbitrary observing times used in early test phases, practice observations made by some schools, and the ever-present complication of conversion of the observation's local time to universal time.

For those cases which matched observation times within 15 minutes, Table 1 shows a comparison of cloud amount measured by the satellite and the ground observers. Entries along the diagonal indicate agreement between the two observations. Entries off the diagonal indicate disagreement. This disagreement may be caused by a difference in field of view, or by detection from the ground of clouds not seen by the satellite.

**Table 1 Ground versus Satellite Cloud Fraction, matched within 15 minutes. 24 observations**

Ground Satellite	Clear	Partly Cloudy	Mostly Cloudy	Overcast
Clear	7	1	0	0
Partly Cloudy	2	3	0	1
Mostly Cloudy	1	0	6	2
Overcast	0	0	0	1

As summarized in Table 2 below, the two types of observations are in agreement in more than 70% of the cases, and there are fewer cases the farther one gets from the diagonal (1-, 2-, and 3-class errors). This level of agreement is fairly consistent with what we see when matching observations from 2 different satellites with differing resolutions. Furthermore, close analysis of those cases showing disagreement has the potential to give us

greater understanding of the causes for the discrepancy.

**Table 2 Summary of Errors in Table 1**

Agree	1 Class	2 Class	3 Class
17	5	2	0

### 3.6 Reward and Evaluate

Rewards have been developed for participating students: a S'COOL Cloud Observer logo has been made in decal form. This decal is given **only** to students who have actually been involved in making cloud observations. A downloadable certificate of participation is currently being finalized, for use at the discretion of each teacher. Other options, such as teacher workshops or summer camps, are currently under study.

Although the project is now in an operational phase, we continue to adjust and add to it. To this end, a teacher survey is available on-line to facilitate feedback on the project from participating teachers. Feedback via e-mail is also welcomed at any time as teachers notice things which need improvement or explanation.

## 4. SPECIAL EVENTS

### 4.1 NASA/CNES Demonstration

In conjunction with the beginning of the operational phase in April 1998, the S'COOL project was put forward as a possible demonstration project for a joint NASA/CNES educational cooperation. This cooperation was to be launched on May 13, with a trans-Atlantic demonstration featuring US First Lady Hillary Clinton in Paris, NASA Administrator Dan Goldin in Washington, DC, and a variety of other American and French dignitaries at these two sites and in Brooklyn, NY. Following a month of intensive international negotiating, the demo was indeed carried out. The students involved - mostly at the middle school level - deserve much praise for preparing and carrying out this demonstration in short order and under heavy scrutiny. The demonstration featured an Internet-based presentation of cloud observations carried out by students at each site, and a comparison with NOAA or Meteosat satellite data taken over the same area at the same time. Even this limited set of observations (3 sites on a single day) illustrated some key reasons why the school project was developed: multi-layer clouds, contrails, etc...

This event gave S'COOL access to additional resources and technology options which will continue to be used for the project. These include Internet-based presentations and a message board which will be used to allow more interaction among S'COOL participants. The event also enabled us to prepare and print a French-language version of the S'COOL poster, which is now available to participants in French-speaking areas.

## 4.2 School Visits

Following the NASA/CNES event, two of the authors (L. Chambers and C. Green) traveled around Europe visiting half a dozen participating schools; while A. Racel visited Washington schools and M. Haefelin those in Brooklyn. Throughout the year, we also visited a number of participating schools in the US, as travel plans permitted. A S'COOL "Wall of Fame" marking the location of each participating school is on display in the hallway where CERES researchers work, to enable them to make S'COOL visits a part of any trip they may take. These school visits are a very important element of S'COOL, allowing us to take the scientific message behind the project directly to the children. As a Swiss elementary school teacher said: "Continue thus and persuade your colleagues to do the same. It is the truest way to 'germinate' vocations".

## 5. LEARNING OPPORTUNITIES

This section summarizes a few of the learning opportunities that the authors have observed while visiting classes or corresponding with teachers.

### 5.1 Observation skills

An elementary school teacher in Michigan has used this project as an opportunity to foster observation skills in her students. Every day before class, they sit out in the courtyard and quietly observe their surroundings: seasonal and weather changes, animal life, vegetation, etc. The project also provides students with a motivation to actually learn how to identify clouds.

### 5.2 Math skills

An elementary school teacher in Virginia reports that her students are so excited about this project that they want to perform some of the calculations of unit conversions themselves rather than relying on an Internet calculator page. Addition and division are routinely exercised in preparing a class consensus for the value of fractional cloud cover, temperature, etc.

### 5.3 Writing/descriptive skills

The same elementary school teacher in Virginia has her students writing similes and descriptions of what they see while outside making the cloud observations (i.e., "the clouds look like moldy bread"). These are reported with their observations in the comments section of the report form, and always result in close attention when their reports come in to NASA.

### 5.4 Technology Skills

An elementary school teacher in South Carolina, among others, reported that this project was a good way

to begin introducing the Internet and computer technologies to her students.

## 5.5 Life Skills

An elementary school teacher in France reports that he uses this project to help teach his students about responsibility and being punctual. We rely on them to make the observations correctly and at the right time.

## 5.6 Scientific curiosity

Middle school students in Paris were observed making relative humidity measurements following the simple directions on the S'COOL poster. They were rather uninterested until they got to the last step and observed the change in temperature for the wet-bulb reading. This first-hand experience provided an entry for learning: why did this happen?

During visits to classrooms, all sorts of questions are raised: the ozone hole, El Niño, and global warming are typical, reflecting the students' awareness of current weather news; but also questions about tornados, the phases of the moon, the correlation between dew and rain, how satellites stay in orbit, and many other topics. These reflect young minds full of curiosity, and willing to ask questions about things they don't understand.

## 6. CONCLUDING REMARKS

The CERES S'COOL project is now available to all interested teachers. Registration information should be sent to NASA Langley (see contact information below). Teachers can participate at their convenience, when it best fits into their curriculum

## 7. REFERENCES

1. Chambers, Lin H., and David F. Young, and Anne M. Racel, "The CERES S'COOL Project: Development and Operational Phases," Proceedings of the Seventh Symposium on Education, American Meteorological Society, January, 1998, pp. 90-93.

## 8. CONTACT INFORMATION

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